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ABSTRACT

Although women comprise the majority of the population, fewer than 9 percent are employed as scientists and engineers. Research indicates that girls have poorer attitudes toward science, enroll less often in science courses, demonstrate lower achievement levels in science, and have fewer experiences with science materials or instruments. Among the factors identified as contributing to the dearth of girls and women in science courses and careers are social factors (role models, sex role stereotyping), educational factors (enrollment patterns, parent/teacher expectations, classroom and extracurricular activities), and personal factors (spatial visualization). This paper examines each type of factor and suggests ways to eliminate negative ones. Briefly, the effect of sex/role stereotyping of physical science courses and careers as masculine deters entrance by, and retention of, adolescent girls. Furthermore, the lack of female role models has a negative effect, particularly on early adolescent girls. In addition, girls have fewer opportunities to develop spatial visualization skills, which may be an important factor in science achievement. However, the most critical difference occurs within science classrooms. Research shows that girls have fewer experiences with science instruments, materials, or techniques. This difference must be addressed by every science teacher to eliminate inequalities in science education. (Author/JN)

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The Disadvantaged Majority: Science Education for Women

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Abstract

Although women comprise the majority of our population, fewer than 9% are employed as scientists and engineers. As the nation addresses the need for improved scientific literacy as well as for increased numbers of scientists, technicians, and engineers, the role of women can no longer be ignored. Research indicates that girls have poorer attitudes toward science, enroll less often in science courses, demonstrate lower achievement levels in science, and have fewer experiences with the instruments or materials of science.

Many factors have been identified as contributing to the dearth of girls and women in science courses and careers. Among them are social factors (role models and sex role stereotyping), educational factors (enrollment patterns, parent/teacher expectations, classroom and extracurricular activities), and personal factors (spatial visualization). This paper examines each type of factor and suggests ways to eliminate negative ones. Briefly, the effect of sex/role stereotyping of physical science courses and careers as masculine deters the entrance into and the retention of adolescent girls. Furthermore, the lack of female role models in science has a negative effect, particularly on early adolescent girls. In addition, girls have fewer opportunities to develop spatial visualization skills than boys do. Such skills may be an important factor in science achievement.

However, the most critical difference in the science education of boys and girls occurs within the science classrooms. Research shows that girls have fewer experiences with the instruments, materials, or techniques of science. This difference must be addressed by every science teacher in every science classroom to eliminate inequalities in science education. As long as the majority of our citizens have fewer opportunities to observe natural phenomena, to use scientific instruments to perform science experiments, or to go on science-related field trips, they are disadvantaged in terms of their science education.

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The Disadvantaged Majority: Science Education of Women

> Our children and our students are participants in a complex process that equips one sex with math, science, and technical skills indispensable to functioning in the adult world, while it fails to encourage the same development in the other sex. Although the lives of individual women are the most negatively and directly affected, the loss to both sexes is immense. (Skolnick, Langbort, & Day, 1982, p. 2)

Introduction

In the United States women comprise approximately 50% of the work force, yet only 9% are employed as scientists and engineers. Factors contributing to this situation have been analyzed in research studies in both the United States and Great Britain. Explanations for the lack of women in science have ranged from differences in spatial abilities linked to a sex-linked gene (Head, 1979) to differences in early childhood toys and games (Hardin & Dede, 1973). Although societal, educational, and personal factors are all involved, differences within the science classroom may be the basic reason why fewer women study science or pursue scientific careers.

Rationale

Although the lack of women in advanced science courses and in scientific and technological careers is accepted, the causes of this situation are argued. Some maintain that society itself is responsible; others argue that biological differences are the reason; still others suggest that Western culture is at fault. The pervasiveness of the problem and the complexity of its underlying causes defy simple solutions. In the past, researchers have examined sociological, cultural, biological, or educational factors in isolation. Although their studies have explicated the complexity of the problem, they have provided few pragmatic solutions.

This paper synthesizes previous research from sociology, science education, mathematics education, and psychology with current data from the National Assessment of Educational Progress (NAEP) in the attempt to identify causes and to formulate practical solutions.

Problem

The 1977 National Assessment of Educational Progress' survey of science contained items assessing both understanding of science and attitudes toward science (NAEP, 1978a). Achievement differences have been found between boys and girls at ages 9, 13, and 17. Girls average between 1.6 and 2.5 percentage points below the national mean on every cognitive item. In order to understand these achievement differences, responses to questions concerning attitudes toward, opportunities in, and beliefs about science have been analyzed (Kahle & Lakes, in press). Girls' responses to National Assessment items concerning opinions of science classes and feelings toward science as a career are consistently negative (NAEP, 1978b). Thirteen and, especially, 17-year-old girls respond that science courses consist of 'facts to memorize,' and they describe science classes as 'boring.' Girls also answer that they do not like to attend science classes and are often afraid to ask questions. Although 9-year-old girls respond that science does not make them feel 'successful,' most of their feelings are positive and comparable to those of 9-year-old boys. However, by ages 13 and 17, girls state that not only does science fail to instill feelings of 'confidence,' 'success,' or 'curiosity,' but also that it makes them feel 'stupid.' Responding to questions concerning science as a career choice, 13 and 17-year-old girls feel that working in science would not 'be fun,' would be 'too much work,' and would not be an endeavor they 'could do well.' In addition, fewer girls than boys want to 'work with scientists to solve problems,' 'make field studies; or 'read science articles.' They are less interested in learning about science careers.

Additional responses provide insights into the girls' perceptions of science and its impact on their everyday lives. For example, 17-year-old females find science useful in choosing foods and vitamins as well as in cooking, but they do not consider science involved in driving a car. Additional data indicate that neither 13- nor 17-year-old girls think that they use scientific

methods in solving problems or in planning their lives. Generally, secondary school girls have little faith in science's ability to solve problems concerning agriculture, meteorology, energy, warfare, overpopulation, and conservation. Female responses to attitudinal items overwhelmingly document poorer attitudes toward science, less understanding of science, and less interest in scientific careers.

Research

Since poor attitudes are directly related to lower achievement levels (McClosky, 1976) and to lower enrollments in elective science courses, factors contributing to negative attitudes must be understood and ameliorated. Three types of factors have been identified: social (role models and sex role stereotyping); educational (enrollment patterns, parent/teacher expectations, classroom and extracurricular activities); and personal (spatial visualization). These specific factors have been selected because research substantiates their effects on the learning of science by women.

Societal Factors

One societal factor affecting attitudes toward, achievement in, and attrition from science by women may be the lack of role models (VanFossen, 1977; Smith, 1974; Graham, 1970). In 1950 the U.S. Department of Labor reported that women were primarily employed in only 20 of the 420 jobs listed in the census of occupations; by 1970 that fact had not changed (U.S. Department of Labor, 1980). Skolnick, et al. (1982) relate that although women constitute 71% of teachers and 99% of secretaries, they make up only 4% of engineers and 1.2% of electricians. In secondary schools, only 24% of science teachers are women, and it may be assumed that most of them teach biology. Female role models are not prevalent in science.

However, Vockell and Lobonc (1981) in a study of coeducational and girls' schools found that the presence or absence of female science teachers did not influence girls' enrollment or achievement in science. Rather, they found evidence that sex role stereotypes were instrumental in influencing girls' choices of science courses and careers. They studied the effect of a female's perception of a field as 'masculine,' 'feminine,' or 'neutral' on her academic and career choices using subjects enrolled in coeducational public schools and in girls' schools, run by religious orders.

Girls in public schools selected subjects traditionally viewed as 'masculine' such as calculus, chemistry, and physics less often than males; and in spite of equal abilities, they performed less well than their male peers. Concommitantly, fewer indicated an interest in 'masculine' careers such as engineer, physicist, or mathematician. Other science areas traditionally are stereotyped as 'neutral;' these include most medical and the biological areas. Girls in coeducational schools enrolled and performed well in biology courses and indicated strong desires for careers in the life sciences.

In single sex schools, the differences noted above were not found. In an environment where they were not socially ostracized for success in a field perceived as 'masculine,' girls enrolled and achieved in physical science and in mathematics as well as in the natural sciences. In addition, they indicated interest in a range of scientific and technical careers.

Studies in Great Britain also report the effect of sex stereotyping on the enrollments of girls in science, particularly physical science, classes (Ormerod, 1975; Entwistle & Duckworth, 1977). Research in this area suggests that sex stereotyping is more marked in coeducational schools because students in that environment are more likely to "acquire a perceived gender" (Entwistle & Duckworth, 1977, p. 70).

Educational Factors

Bowyer, Linn & Stage (1980) report that the differences in male and female achievement scores on the two recent National Assessment surveys in science and mathematics are directly proportional to the number of semester hours taken in science and mathematics courses. For example, on the whole, females take one-third of a semester less mathematics and one-half of a semester less science than males, and this fact alone accounts for the achievement differences.

As Fox (1980) explains, comparisons of mathematical ability between 17-year-old boys and girls are truly comparisons between students with 3-4 years of mathematics and those with 1-2 years of math. In a typical school district girls may outnumber boys in advanced eighth grade math classes, but by twelfth grade twice as many boys as girls are enrolled in calculus (Skolnick, et al., 1982). Many researchers think that the lack of courses in mathematics effectively eliminates most women from careers in the sciences (Iker, 1980; NSF, 1980; Boywer, in Trowbridge, et al., 1981). Lack of training in mathematics may explain Head's findings that although females comprise over one-third of all students in higher education in England, they account for less than one of every seven undergraduates in physics and for fewer than one in six in chemistry (Head, 1979). Skolnick, et al. suggest that in this country, differences in number of mathematics courses may explain why twice as many college-bound senior boys as girls have had three years of physical science. Typically, a girl who wishes to pursue advanced science courses finds her fear that 'girls don't become scientists' reinforced clearly by the ratio of boys and girls in the classroom (Skolnick, et al., 1982, p. 40).

Differences in parent and in teacher expectations also affect the performance and enrollment patterns of women in science. Low parental expectation, evaluation, and encouragement may discourage girls from excelling in scientific areas (Graham, 1978; Kaminski, 1976; Fox, 1976). Bowyer states that boys in school are "valued for thinking logically, independently, with self-confidence, and an appropriate degree of risk taking." Girls, however, are "valued for their emotional expressiveness, sensitivity to others, dependency, and subjective thinking" (Bowyer, in Trowbridge, et al., 1981, p. 97). In elementary school and high school, girls and boys interested in science are treated differently by parents and teachers. "Girls found ambivalence, lack of encouragement, and messages that what they were doing was inappropriate, impractical, or unacceptable. Boys encountered much wider acceptance of their intentions as appropriate and admirable, particularly in terms of future economic status and a successful career" (Brown, Aldrich, & Hall, 1979, p. 1). As Skolnick, et al. (1982) explain, "While for boys math and science successes can heighten masculine self-esteem, girls must walk a tight rope between pride in their achievement on the one hand and a threat to their feminine self-image and social support on the other." (p. 42)

Most critically, however, the recent national surveys indicate inequities within the science classroom. Although achievement differences in science between boys and girls are not apparent until age 13, differential science experiences are documented as early as age 9. Briefly, by age 9, girls record significantly fewer opportunities to work with science materials and instruments, to observe natural phenomena, and to participate in extracurricular science activities.

In order to determine the reason for these disparities in science opportunities, a series of parallel questions was analyzed. For example, responses to items such as 'Have you used a balance?' and 'Would you like to use a balance?' were compared. Although many elementary school girls report wanting to observe natural phenomena such as watching a seed sprout or seeing the moon through a telescope the percentage of those who have done so is much lower. They also relate significantly fewer opportunities to use scientific instruments such as a meter stick, scale, telescope, microscope, compass, stopwatch, and balance, although they wish to use them. In addition, girls have fewer opportunities to participate in common laboratory experiences, although their interest in doing such activities is equal to the interest expressed by boys. As a result, at age 17, or when they graduate from secondary school, girls have had significantly fewer opportunities to experiment with magnets, electricity, heat, solar energy, and erosion (NAEP, 1978b). Furthermore, there is a clear difference in girls' participation in traditionally feminine versus masculine tasks. Although secondary school girls respond far below the national averages concerning experiences with electrical or mechanical tasks, they respond above it in number of times they have cared for an unhealthy plant or animal.

A similar analysis of extracurricular science activities also reveals marked differences between males and females at ages 13 and 17. Secondary school girls participate less often than boys in all extracurricular science activities assessed. Females range from 1.3% to 7.6% below the national mean on activities such as watching TV science shows; reading books, magazines, and newspaper articles on science; and working with science projects or hobbies (NAEP, 1978b).

In addition, although girls indicate an interest in taking a variety of science related field trips, fewer girls have opportunities to do so. This lack of extracurricular science experiences augments the overall deficiency in science for girls.

Personal Factors

A wide range of studies indicate that women are slightly more field dependent than men, and others suggest that more women score on the external end of the locus of control scale. However, research has indicated that these differences are not extreme enough to affect the entrance and success of women in science (Witkin, et al., 1977; Kahle, 1982). Another personal variable has been suggested. According to Maccoby & Jacklin (1974), the average score of a group of males is slightly higher than that of a group of females on tests measuring spatial visualization. Spatial visualization may be defined as the ability to manipulate an object or pattern in the imagination. Some researchers maintain that male spatial abilities are responsible for the higher achievement and interest levels boys express in math and science (Skolnick, et al., 1982). Treagust's research concerning infralogical groupings suggests that lower science achievement levels of 13 and 17-year-old girls are related to their slower development of spatial visualization. He maintains that lower spatial abilities of teen-age girls are due to slower developmental patterns rather than to the school curriculum which in the lower grades is largely the same for all students (Treagust, 1980).

However, two recent reports dispute his findings. First, Linn's (1982) meta-analysis of spatial ability research by gender reveals no significant differences between males and females before, during, or after puberty. In addition, the National Assessment data reported here indicate that girls and boys do not have equal experiences with science materials within science classrooms; such opportunities are critical in the development of spatial abilities. Fenneman & Sherman (1977) state that "covarying out the differences between the sexes in number of space related courses taken eliminates the sex-related differences in spatial visualization. This is consistent with the hypothesis that practice and relevant experience are factors in the difference between the sexes in spatial visualization" (p. 66). Skolnick, et al. (1982) maintain that experience with manipulative materials such as constructing and examining three-dimensional structures, graphing, and modeling are critical to the development of spatial visualization skills.

Implications

Although societal, educational, and personal factors have been identified which affect the science education of women, remedies are possible within the science classroom. The National Assessment data concerning girls' experiences with, activities in, and understanding of science indicate that different teaching strategies must be adapted from kindergarten through graduate school. For example, laboratory and demonstration activities which provide spatial experiences may enhance the spatial abilities of females. As Treagust (1980) points out, "A student with poorly developed spatial abilities should not be taught primarily by verbal means" (p. 95). Skolnick, et al. (1982) suggest a variety of science activities which range from recognizing similar shapes from different perspectives to converting two-dimensional patterns to three-dimensional objects and vice versa. In addition, girls must be encouraged to enroll in mechanical drawing, industrial education, and other courses which have activities designed to develop spatial abilities.

In science courses, laboratory groups must be carefully structured so that girls actually work with science apparatus. Instructors can pair boys with boys and girls with girls during science experiments and recruit females to do science demonstrations. According to Skolnick, et al. (1982), "Single sex groups are important because girls have not had the informal math and science experiences boys have had and may be intimidated in mixed-sex competitions" (p. 55). After girls have achieved more confidence, teachers may implement mixed-sex groups.

Science teachers as well as school counselors and administrators must guard against unconscious bias in their presentation of science courses and careers or in their scheduling of science classes. For example, physics should not conflict with honors English, advanced French,

or other courses traditionally selected by girls. The written and verbal use of non-sexist language in the classroom as well as in the text and other instructional materials is critical. Furthermore, the contributions of women must be portrayed seriously in narrative as well as illustrative materials. The inclusion of women photographed in lab coats is inadequate; their real contributions must be discussed. Research indicates that the sex-role stereotyping of science as a masculine endeavor is one of the most powerful deterrents to adolescent girls enrolling and excelling in science courses. If the repeated message from teacher and text is that scientists are males, adolescent girls, unsure of their femininity, will shy away from science or, if enrolled, perform poorly.

Science education for girls must be augmented also by extra-curricular science activities. Boys may have greater opportunities for science activities through membership in the Boy Scouts, Boys Clubs, or other groups. Participation in these groups may be partially responsible for the differences in field trip experiences between boys and girls. Male groups are more likely than their female counterparts to visit weather stations and electric plants and to do electrical and mechanical projects.

Although the function of role models has been questioned in improving attitudes toward or in increasing the number of women in science, many studies suggest a positive effect. Recently both the National Science Foundation (1982) and the American Association of Physics Teachers (1975) have developed films and slide/tape presentations of women in science. These should be included in the science curriculum. In addition, universities such as Stanford University and Massachusetts Institute of Technology have successfully used undergraduate women in science and engineering to recruit high school girls to those fields. Perhaps, the most effective role models for science classes are women or girls only a few stages ahead of one's students. Girls might form science clubs at both the elementary and junior high levels to encourage those in the lower grades. Social perceptions of acceptance and 'belonging' could be fostered, and perhaps the negative attitudes developed between age 9 and 13 could be ameliorated. During the early high school years, girls should have the opportunity to speak with both collegiate undergraduate and graduate women in science as well as professional female scientists and engineers.

Summary

The majority of our citizens enroll in fewer science courses, perform fewer science activities, achieve at lower levels in science classes, understand science less well, and have negative attitudes about the role of science in their lives and in society. Research indicates the causes of this situation, and a synthesis of research findings suggests possible solutions. The strategies suggested in this paper to alleviate this situation can occur in every science classroom. Conscious efforts may be needed in the beginning; but as students, teachers, counselors, and administrators practice these strategies, they will become routine. The recognition of inequities in science classrooms and the implementation of remedial instructional and curricular strategies is a critical first step in improving the science education of women. Science teachers as well as educators of science teachers should be cognizant of these strategies.

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